OVERVIEW OF THE CURRENT AND PLANNED ACTIVITIES IN THE FRENCH UNDERGROUND RESEARCH LABORATORY AT BURE

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ABSTRACT

In November 1999 Andra began building an Underground Research Laboratory (URL) on the border of the Meuse and Haute-Marne departments in eastern France. The research activities of the URL are dedicated to reversible, deep geological disposal of high-activity, long-lived radioactive wastes in an argillaceous host rock. The studies covered four complementary aspects: acquisition of data (waste packages, material behaviour and clay medium), repository design and reversibility studies, analysis of the long term behaviour of the repository, safety analyses. For the next phase starting in 2007, Andra will carry out integrated tests of a technological scope, i.e. trial drift, demonstrator of current drift. The results should make it possible to assess the safety of a disposal over several tens and even hundreds of thousands of years and submit in 2015 a file for permission request for the HLW and ILW deep disposal.

1. Introduction

In November 1999 Andra began building an Underground Research Laboratory (URL) in eastern France. The research activities of the URL are dedicated to reversible, deep geological disposal of high-activity, long-lived radioactive wastes in an argillaceous host rock. The objectives of the URL for the 1999-2005 years were mainly the *in situ* characterization of the physical and chemical properties of this rock. The results of this research are presented in the file “2005 Argile” [1].The studies covered four complementary aspects:

- Acquisition of data concerning the waste packages, material behaviour and clay medium,
- Repository design: waste conditioning, repository architecture and integration in a geological site, operating modes and reversibility,
- Analysis of the long term behaviour of the repository and modelling of its thermal, mechanical, chemical and hydraulic evolution,
- Long term safety analyses.

For the next phase starting in 2007 the following activities will be carried out:

- Consolidate data acquired over the period 2002-2005 and conduct long term experiments,
- Carry out integrated tests of a technological scope, i.e. trial drift, demonstrator of current drift, demonstrator integrating clay core, concrete plug and buffer material, prototype of disposal vaults for ILW and HLW,
- Quantify more precisely the safety margins through development of modelling, flow-migration coupling (water-gas), reactive migration in desaturated environment, management of uncertainties and probabilistic methods.

2. URL Site Overview

The target horizon for the URL is a 130-m-thick layer of argillaceous rocks that lies between about 420 and 550 m below the ground surface. Stratigraphically speaking, the depositional period straddles the Callovian and Oxfordian subdivisions of the Middle to Upper Jurassic. Argillaceous rocks contain a mix of clay minerals and clay-sized fractions of other compositions. The clays, constituting 40 to 45% of the Callovo-Oxfordian argillaceous rocks, isolate the groundwaters. Silica and carbonate-rich sedimentary components reinforce the rock and ensure stability for underground construction.

The URL location lies in the eastern portion of the Paris Basin, which covers a major portion of Northern France. The beds are nearly flat-lying with a slight dip of less than 1.5° westwards towards the centre of the Basin. The deep-water depositional environment of the Callovo-Oxfordian argillaceous rocks created a homogeneous layer that is continuous over most of the Paris Basin. The stratigraphy of the URL site consists of Jurassic limestones, marls and argillaceous rocks (Figure 1). The major overlying limestone units are the Tithonian Barrois limestones, forming a surface veneer over the URL site, and the Oxfordian limestones from about 150 to 400 m in depth. Between the Tithonian and Oxfordian limestones is a 150-m-thick sequence of mixed Kimmeridgian argillaceous rocks, marls and limestones. Underlying the Callovo-Oxfordian argillaceous rocks are the Bathonian and Bajocian Dogger limestones and dolomitic limestones [9].

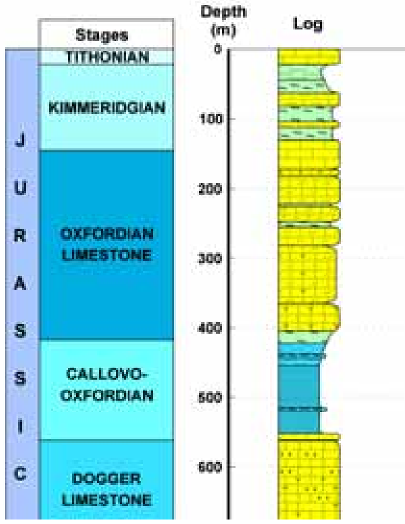

Figure 1 Stratigraphic column at the URL site

3. Construction of the URL

Two 500-m-deep shafts provide access from the surface to the argillite host rock. The main shaft has a 5-m diameter and allows access for personnel and equipment, material extraction and ventilation. The 4-m auxiliary shaft located 100 m away from the main shaft serves the ventilation system and provides not only mine safety, but also a second access for lowering equipment. From the shafts, the laboratory has two levels of access drifts at depths of 445 and 490 m (Figure 2). The upper drift will have a simple T-shaped configuration and a total length of about 4 m. It provides access to boreholes in order to monitor shaft-sinking effects through the argillaceous host rock [5]. The five hundred metres of drifts at the 490-m level constitute the key experimental level of the laboratory. Experimental zones are located in a specific area in order to allow construction and drift-fitting work to take place at the same time.

3.1. Shaft-sinking method

The choice of a suitable shaft-sinking method was limited to drilling and blasting. The approach was chosen over shaft-drilling methods for several reasons, including the lack of experience with shafts as large as the laboratory’s. With a view to saving time, raise-boring was ruled out because both shafts are being sunk in parallel from the surface. The most important consideration, however, was the need to conduct scientific activities and observations in the shaft during construction, which would have been very difficult in a shaft-drilling operation. The selected shaft-sinking method uses a multistage platform which supports all shaft-construction operations, including drilling and blasting, mucking and applying the concrete liner.

The support system was installed directly and immediately after excavation. It consists of bolts and wire mesh covered with shotcrete in order to prevent spalling. The final lining consists of concrete poured in 3-m sections at a time. The thickness of the concrete ring is approximately 30 and 45 cm in carbonates and argillaceous rocks, respectively. In addition, the stress within that lining is recorded by vibrating wires that are fitted while pouring the concrete ring.

3.2. Drift-opening methods

Due to the building requirements of the Bure URL, the drill-and-blast method was applied at a depth of 445 m and the pneumatic-hammer method to open drifts at a depth of 490 m. Supports consist of 2.4-m bolts and sliding arches. Down at 490 m, the floor is reinforced with bolts. A shotcrete lining sprayed over wire mesh prevents spalling.

Since one of the purposes of geomechanical measurements is to assess potential convergences and stresses on a final lining, specific zones have been instrumented for convergence measurements and measurements on supports. The observed convergences depend on the orientation of the drifts and on the excavation and support methods being used. After one year, the measured convergences are in the order of approximately 10 cm and deferred deformations (creeping) are observed.

4. Experimental programme carried out in 2004-2006

Studies and experimental work cover three major aspects in the URL drifts:

- Containment capability of the host formation
  This containment capability comes from the specific physical characteristics of the rock and the physico-chemical characteristics of the interstitial fluids and their interaction with the rock. The fundamental physical characteristic is permeability. This property is studied through various specific tests [4]. The chemical characteristics of the interstitial fluids condition the mobility of the various radionuclides likely to be found in the natural environment [6]. The studies focus on knowledge of the geochemistry of the interstitial fluids in equilibrium with the minerals in the rock and on the diffusion and retention capabilities of the radionuclides.
- Creation of damaged and disturbed zones associated with drift excavation
  The main purpose of the studies on this topic is to investigate how the rock reacts to the excavation of shafts and drifts, and the associated development of the damaged and disturbed zone [8]. Several techniques and methodologies used at Bure URL had been previously developed at Mont Terri Rock laboratory [7]. Damaged zone (EDZ) and disturbed zone (EdZ) were characterized during monitoring of the shaft and excavation of the experimental drift at 445 m (Figure 2).
  Measurements are grouped in the drift sections and within specific shaft excavation monitoring experiments. These experiments include a set of boreholes with instrumentation installed in advance in the drift.

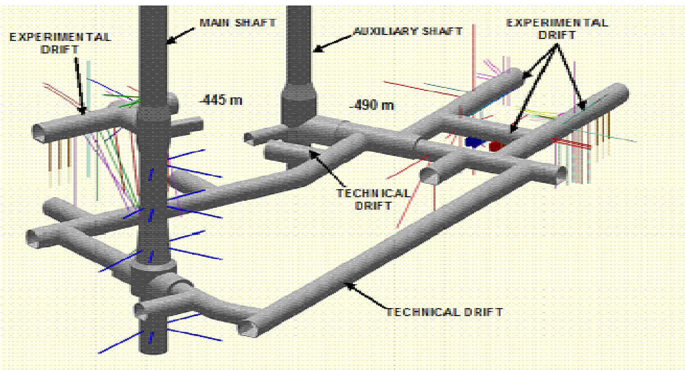

Figure 2 Detailed view of experimental drifts

- Assessment of sealing zone concept
  The sealing of a drift is a major issue when considering the disposal construction options. It involves designing systems to re-establish the original low permeability of the formation by overcoming potentially negative effects from the damaged zone surrounding the drifts and shafts. The system studied for the Andra project is called “anchor key”. An anchor Key is a 30 to 40 meter long drift, filled with swelling clay (bentonite). Every five to ten meters a slot is made around the drift with a saw. This slot is filled with swelling clay and this device interrupts a potential flow along the drift. Experiments on the feasibility of an anchor key have been conducted, firstly in the Mont Terri Rock Laboratory [3] and subsequently in the KEY drift at the main level of the Bure URL.

5. Repository design and 2007- 2015 Programme

Through its construction and experimental activities, the laboratory has helped Andra to develop a concrete approach with a view to proposing suitable architectures and management methods for a repository [2].
The future work in the laboratory will include the life-size construction of the different components of a disposal facility, such as the cells or the plugs for cells and drifts. Once specifications will be set, it will be possible to draw a concrete preliminary design integrating the specific characteristics of the selected zone for the implementation of the repository.

5.1. Main repository features

The design of the repository is regulated by the safety approach that will lead to the sizing and specification of containment barriers with a view to:

- preventing water circulations (low permeability of the geological environment and of sealing and repository structures);
- immobilising radionuclides at the package level by creating or maintaining favourable physicochemical conditions for that retention;
- retarding and mitigating any potential migration of radionuclides outside disposal cells.

Hence, in the framework of the Meuse/Haute-Marne project, investigations have led to the proposal of a repository with the following features [2]:

- it is located at the centre of the layer in order to maximise the thickness of the impermeable geological formation and to ensure the best containment possible;
- disposal areas for that waste category are compartmentalised in order to reduce intrusion risks or failure consequences. The different waste categories are emplaced in separate disposal areas in order to simplify their safety assessments and to ensure the thermal independence of the different areas;
- structures have a simple geometry with circular profiles that are considered as the most stable and are lined in such a way to be stable for 100 years;
- materials coming in contact with the rock, whether they are natural (clay rock) or man-made (concrete, steel, plugging or backfill materials) help to maintain the physicochemical conditions retarding package alteration and degradation in order to limit the release of radionuclides in the biosphere.

5.2. Planned activities for the 2007-2015 period

For the next phase starting in 2007 the following activities will be carried out:

- Consolidate data acquired over the period 2002-2005 and conduct long term experiments (diffusion, porewater characterization, hydrothermal coupled phenomena), i.e.: hydromechanical evolution of the shafts and drifts, continuation of installed experiments beyond 2006, setting up experiments on rock/materials, diffusion experiment in the long-term (2007). These studies will lead to quantifying more precisely the safety margins through development of modeling (Flow-migration coupling (water-gas), reactive migration in desaturated environment, management of uncertainties and probabilistic methods

- Carry out integrated tests of a technological scope, i.e. trial drift (2007- 2008) and demonstrator of current drift (2008), construction of a lasting concrete cladding (2009-2010), demonstrator integrating clay core, concrete plug and buffer material (2007-2009), prototype of a disposal vault for ILW wastes (e.g. : l=80m) (2008-2009), 2 HLW horizontal demonstrator vaults (e.g. : l=40m)(2008-2010).
  These tests will include detailed studies of individual components, i.e. ILW and HLW disposal packages, handling equipment of packages through an international program (ESDRED), sealing of drifts, interfaces packages/handling equipment/vault and construction and closing of the vaults. In addition, detailed studies of bodies of architecture will be carried out. The studies will focus on shafts, infrastructures of the shafts zone, thermal dimensioning of the HLW area and layout and dimensioning of nuclear surface installations.

6. Conclusions

The experimental programme of the URL addresses the two major issues of demonstrating the natural isolation capability of argillite and the feasibility of constructing and operating a repository without compromising those isolation properties. Through its construction and experimental activities, the laboratory has helped Andra to develop a concrete approach with a view for proposing architectures and management methods for a repository.
The future work in the laboratory will include the life-size construction of the different components of a disposal facility, such as the vaults or the sealing for vaults and drifts. At the end of the 2006 law on nuclear waste management, it will be possible to submit to the safety authorities a concrete design integrating the specific characteristics of the selected zone for the implementation of the repository.

7. References

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